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QUANTITATIVE ELECTROENCEPHALOGRAPHIC VALIDATION OF LEFT AND RIGHT TEMPORAL LOBE SIGNS AND INDICATORS IN NORMAL PEOPLE [1]

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Summary.—During a single 20-min. exposure to partial sensory deprivation, the average duration of alpha rhythms over the left temporal lobe (T3) increased significantly compared to that for the right homologous region (T4). The percentage changes (increase) over time in the duration of alpha rhythms over the left temporal lobe but not the right temporal lobe were significantly correlated (.64) with histories of automatic behaviors (cessation of awareness) while only the relative increases over time in the durations of alpha rhythms over the right temporal lobe were correlated with histories of vestibular-auditory experiences (.42). The results suggest construct validity for differential hemispheric sources of some specific clusters of complex partial epileptic-like experiences that have been inferred to reflect the continuum of temporal lobe lability.

Construct validity has been considered an essential element of psychometric verification. The summed quantitative incidence of subjective experiences that are similar to those reported by patients with complex partial epilepsy (Gloor, 1972; Bancaud, Brunet-Bourgin, Chauvel, & Halgren, 1994) has been hypothesized to reflect a continuum of temporal lobe lability (Persinger & Makarec, 1987, 1993) or an epilepsy spectrum (Roberts, Gorman, Lee, Hines, Richardson, Riggle, & Varney, 1992) along which all human brains are distributed. We have employed the metaphor that greater electrical lability (defined as the increased probability either to discharge or to be recruited into a paroxysmal sequence) of aggregates of neurons within the subcortical regions (hippocampus, amygdala) of the temporal lobes is associated with a more frequent occurrence of the different types of experiences that are associated with those limbic structures. A quantitative relationship between the proportion of neurons activated deep within these limbic regions and the qualitative shifts in subjective experiences (from odd sensations to automatisms) has been experimentally demonstrated in epileptic patients by Babb, Wilson, and Isokawa-Akesson (1987).

Makarec and Persinger (1985, 1987, 1990) reported that the duration of bipolar alpha rhythms per unit time over the temporal lobes (T3, T4) but not the occipital lobes (O1, O2) of normal subjects was significantly correlated with the numbers of temporal lobe (complex partial epileptic-like) signs

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and symptoms which had been endorsed on the Personal Philosophy Inventory. We have extended the concept (Andersen & Andersson, 1968) that the individual brain's relative proportion of slower electrocortical wave activity (alpha rhythms vs alpha frequency) which suggests driving or coordination by subcortical neuronal oscillators, reflects the relative contribution of subcortical structures to phenomenological experiences. Consequently, people who exhibit more frequent durations of alpha rhythms or greater intraindividual coefficients of variation for the occurrence of these signatures over time should experience a richer although intermittent contribution from limbic sources than individuals whose brains remain vigilant (reflected as desynchronized fast activity) to exogenous stimuli.

The next logical step in this research was to identify the distinct associations of the subdomains for these experiences within the two cerebral (temporal) hemispheres. Previous correlations between scores for clusters of experiences that are typical of temporal lobe activation and the durations per unit time of cortical alpha rhythms involved bipolar (left vs right) comparisons. The absolute or relative amounts of the durations, e.g., per minute, of alpha rhythms during simultaneous monopolar measurements for the left and right temporal lobes separately (referenced to ear) would allow more specific associations with clusters of experiences by potentially identifying the unique (by partial correlation analyses) shared sources of variance.

Several of our recent psychometric analyses have referred to "left" and "right" temporal lobe indicators. When factor analysis (PA 1; after varimax rotation by SPSS) of all 52 items which constitute the major temporal lobe scale is limited to two factors, each factor is correlated 0.87 and 0.86 with the clusters of items which have been given the names "left" and "right" hemisphericity, respectively (Persinger & Makarec, 1992). However, consistency of sources of variance within a level of scientific discourse may not necessarily generalize to congruence *between* levels of discourse (disciplines). Stated alternatively, strong divergent and convergent validity between various types of psychometric tests does not necessarily reflect the same source of variance within a different level of perspective, i.e., electrophysiological activity within relatively (compared to electrode discrimination) large cortical areas. Consequently, this study was designed to assess whether the durations of alpha rhythms over the right or the left temporal lobes were specifically associated with complementary psychometric categories and factors.

Following approval by the departmental ethics committee and informed consent by the subjects, a total of 23, 21- to 27-year-old first-year university students (10 men, 13 women) were administered the Personal Philosophy Inventory within a portion of the class period typically reserved for routine testing. Within 3 to 6 weeks later, each person was tested singly. While seated in a comfortable chair within a commercial acoustic chamber,

monopolar activity over the left (T3) and right (T4) temporal lobes was measured through silver electrodes (EC2 cream) by a P79 Grass polygraph; the common reference was to the earlobe. The subject's eyes were covered with halves of a ping-pong ball (lined with cotton). Each subject was instructed to relax with eyes closed while sitting in the dark for 20 minutes.

The numbers of alpha rhythm/seconds (defined as synchronous 8- to 13-Hz waves whose amplitudes exceeded the background band, i.e., average peak-to-trough amplitude, by a factor of at least two) per minute for the entire 20-min. record were counted by visual inspection by an experienced graduate researcher who was not familiar with the purpose of the study. To qualify as an alpha second, at least 75% of each successive second (a reliable just noticeable difference for our paper speed) was required to display the rhythmic synchronous activity that typifies this wave structure; each second received a score of 0 or 1. The numbers of seconds per minute which contained alpha rhythms for each subject for the left and the right temporal lobes during the first and second 10-min. periods were then calculated. Alpha rhythm profiles were measured rather than the duration of beta activity or more complicated signatures, because the former are conspicuous and qualitatively simple.

Three-way analysis of variance (MANOVA: SPSS) with one level not repeated (sex) and two levels repeated (left vs right temporal lobe and first vs second half of the period) for the duration of alpha time showed no statistically significant sex differences ($F_{1,21} = 2.06$, $p > .05$). The strongest effect was an interaction for hemisphere (left vs right) and time block (first vs second) ($F_{1,21} = 12.72$, $p < .01$); *post hoc* analyses indicated that the interaction was due primarily to the higher incidence of the proportion of alpha time, i.e., percentage of seconds that exhibited alpha rhythms, over the left hemisphere during the second 10-min. interval ($M = 33\%$; $SD = 28\%$) compared to the first 10-min. interval ($M = 22\%$; $SD = 21\%$) relative to these measures over the right hemisphere for both the second and the first 10-min. intervals which were 22% (27%) and 20% (25%), respectively. Except for the artifactual main (repeated-measure) effect between the first and second block ($F_{1,21} = 5.88$, $p < .01$), none of the other components of the analyses were statistically significant. These results indicated that, during the second half of the 20-min. period, the left temporal region became more deactivated, as defined by enhanced incidence of alpha rhythms, compared to the right temporal region whose level of vigilance did not change significantly.

To estimate the association between the quantitative indicators of synchronized electrical activity within the temporal cortices per 10-min. interval and the traditional clusters of items derived from our (Persinger & Makarec, 1987, 1993) questionnaire from which we infer the quantitative incidence of the phenomenology that has been associated with temporal lobe function,

zero-order and partial correlation analyses were completed between these psychometrically derived clusters of items and two types of electroencephalographic activity. The first type involved the absolute seconds per minute during which alpha rhythms were observed during the 20-min. interval over the left and the right temporal lobes. The means and the standard deviations (*SD*) were 16.7 (14.5) sec. per min. and 12.8 (15.2) sec. per min., respectively (the percentage alpha rhythm times are simply the quotient of these means divided by 60 and multiplied by 100).

The second measure accommodated individual differences by allowing each person to serve as his own control. For this measure the mean numbers of alpha rhythm (sec. per min.) during the second block were subtracted from the mean numbers of alpha rhythm (sec. per min.) during the first block and divided by the alpha time of the first block (then multiplied by 100) for each hemisphere. The means and standard deviations for this measure for the left and right temporal lobes were 44% (62%) and 5% (44%), respectively. [The net changes in alpha sec. were 5.8 (6.6) sec. and 1.1 (7.1) sec., respectively.] Because individual differences are still the primary source of variance in psychological phenomena, and complex neurocognitive properties such as those associated with the sense of self and awareness are emergent from reentrant properties (Edelman, 1989) and "comparator ratios" (Sommerhoff, 1974) rather than secondary to the (suprathreshold) magnitude of the activity, the general hypothesis was that *relative* changes (rather than a single average of raw alpha seconds per minute) in electroencephalographic activity would be more strongly associated with the person's quantitative inferences of temporal lobe phenomenology rather than absolute measures.

The major left-hemispheric (Factor 1) and right-hemispheric clusters (Factor 2) from Persinger and Makarec's (1992) analyses were obtained from each subject's responses to the Personal Philosophy Inventory. In addition, specific subclusters which reflect a traditional left-hemispheric function (awareness), defined as the incidence of "automatic behaviors" (memory blanks, falling asleep in one setting but awakening in another), and hypothesized (Persinger, 1993, 1994) right-hemispheric functions as auditory-vestibular intrusions, e.g., hearing one's name called late at night and pleasant vibrations moving throughout the body before falling asleep, were assessed. One specific cluster, the sense of a presence, i.e., feeling the presence of a spiritual being, an entity, or a Cosmic Consciousness, was also extracted because recent theoretical interest has focused upon the etiology of these phenomena given the relevance to subjective proofs for existence of gods. Both zero-order and partial correlations (with contributions from the other hemisphere held constant) showed no significant correlation ($p > .05$) between the absolute duration of alpha rhythm in seconds per minute during the entire 20-min. session and any of the temporal lobe indicators.

However, the indices of relative changes in EEG activity showed both statistically significant and rational associations with the person's history of experiences which have been inferred to reflect elevated mesiobasal temporal lobe activity. The zero-order Pearson correlations between the percentage increases (second 10-min. interval relative to the first 10-min. interval) of the durations in alpha rhythms over the left and the right temporal lobes, respectively, for the aggregates of items were (all $rs > .42$, $p < .05$) for the left-hemisphere cluster .52 and .45, for the right-hemisphere cluster .52 and .22, for the automatic behaviors .64 and .26, for the auditory-vestibular experiences .43 and .55, and for the sensed presence .26 and .42. Spearman *rho* values did not differ appreciably from the Pearson *r* values. After removing the shared variance with the duration of alpha rhythms over the right temporal lobe, the partial r_p values between the duration of alpha rhythms over the left temporal lobe and the clusters were for left hemisphericity .34, for right hemisphericity .50, for automatic behaviors .64 ($p < .01$), for auditory-vestibular experiences .16, and for sensed presence .22. When the shared variance with the left temporal lobe activity was held constant, the partial correlations between the durations of right temporal lobe activity and these clusters were .19, −.15, −.23, .42 (auditory-vestibular experiences; $p < .05$), and .16, respectively. Visual inspection of the scattergrams and partial plots verified the linearity of these relationships.

To be thorough, each of the major clusters ($n = 5$), including control and lie scales, and subsets ($n = 20$) of clusters from the inventory were correlated with the electroencephalographic measures. The most conspicuous, surprisingly robust and potentially theoretically relevant association occurred between the *average* absolute amount of alpha seconds per minute over the *right* temporal lobe and the person's strength of endorsement of conservative religious beliefs ($r = .63$, $p < .01$) and egocentricity ($r = .43$). There was no association between these belief clusters and the average alpha time over the left temporal lobe ($rs = .15$ and .16, respectively). Neither partial correlation for activity in the alternative lobe nor control for egocentrism changed the magnitude of the association.

This pattern is commensurate with the hypothesis that people with less right cortical temporal lobe activity, i.e., more alpha time, may be more egocentric and exhibit more intense conservative religious beliefs because their experiences are dominated by the linguistic processes and artifacts, i.e., the sense of self, of the left hemisphere (Persinger & Makarec, 1992; Persinger, 1993). In light of the emerging evidence of both a microstructural and electroencephalographic difference between genders within the temporoparietal regions (Reite, Cullum, Stocker, Teale, & Kozora, 1993), it may be of interest that the 10 men in this study were primarily responsible for both the magnitude and the statistical significance of these specific correlations. Con-

sidering the frequent absence of significant mean differences between normal men and women for most psychometric scales yet substantial sex differences for the factor structure of the intercorrelation between the same scales, the present analyses should be completed separately on larger samples of men and women.

The general results support the construct validity of the "temporal lobe continuum" (Persinger & Makarec, 1987) within this normal sample and by extrapolation to the normal population. There were quantitative relationships between the numbers of different signs and symptoms that are classically associated with elevated temporal lobe function and quantitative electroencephalographic activity over this region. It is relevant that the magnitudes of the scores for the clusters of items from which we infer temporal lobe lability or complex partial seizure-like symptoms were within the range of clinical relevance for about one-third of the sample. If the person's experiences and phenomenology are determined by those portions of the brain which are most metabolically active at any given time, then the positive association between these experiences and the greater duration of alpha rhythms over the left temporal region suggests enhanced relative contribution from the input of intralaminar/midline thalamic and (subcortical) mesiobasal temporal lobe pacemaker neurons. The argument would be analogous to the enhanced incidence of alpha rhythms over the occipital region when there is no visual input, e.g., eyes closed, because in the absence of this sensory input aggregates of cortical neurons are synchronized by oscillatory volleys from cellular zeitgebers within the thalamus (Andersen & Andersson, 1968). This model implicitly assumes a reciprocal relationship between the quantitative occurrence of alpha rhythms over the cortices and quantitative enhancement of subcortical activity. Consequently, a net decrease in fast cortical activity should be associated with a comparable increase in subcortical contribution to the concurrent subjective experiences.

The discrepancy between the present study which yielded significant associations between the absolute amount of alpha time and inferences of temporal lobe activity and those of previous studies may be related to procedural differences. Although Makarec and Persinger (1985, 1987) reported moderate correlations (.40 to .50) between the numbers of alpha seconds per minute over the temporal (but not occipital) lobes and scores for the major temporal lobe cluster, the actual means and standard deviations for these alpha indices ranged between 1.5 (1.5) sec. per min. and 5.1 (6.1) sec. per min. and the montage was bipolar (T3 compared to T4). The mean numbers of alpha seconds per minute over each (monopolar) temporal lobe in the present study was approximately three to ten times greater. It is possible that the source of variance responsible for the electroencephalographic correlation with subjective experiences in the original studies (no partial sensory depri-

vation) was masked by greater deactivation of cerebral activity in the present situation and could only be extracted when this additional alpha time was removed by subtraction.

The strength of the quantitative association between the duration of alpha rhythms over the right temporal lobe and reported histories of "sensed presences" was not statistically significant ($.05 < p < .10$) according to the preset criterion. However, the duration of *theta* activity over the right (but not the left) temporal lobe has been associated with a history of sensed presence (Munro & Persinger, 1992). These interexperimental differences suggest that the reported history of a sensed presence may be more specifically related to the processes that produce right- or left-hemispheric discrepancies in theta activity rather than in alpha activity over the temporal lobes. This possibility is supported by the prevalence of "theta bursts" (Verduyn, Hilt, Roberts, & Roberts, 1992) in populations of brain-injured patients who also exhibit elevations of the types of complex partial epileptic-like signs with which the sensed presence is associated (Persinger, 1994).

The propensity for people whose left temporal lobes' activity decreased quickly (as defined by increased durations of alpha rhythms) during partial sensory deprivation to have histories of more automatic behaviors, i.e., memory blanks, is commensurate with the contemporary association between self-awareness, linguistic processing, and left-hemispheric function (Edelman, 1989; Corina, Vaid, & Bellugi, 1992). That this association is specific to left-hemispheric function was indicated by the maintenance of the association after the shared variance with right-hemispheric alpha time had been accommodated. On the other hand, the specific cluster of auditory-vestibular experiences was associated specifically with the amount of alpha time over the right hemisphere. Although the expected symmetrical associations between alpha time and the specific clusters of subjective experiences were not observed, the absence of this symmetry could have been confounded by the asymmetric increase in alpha rhythms across time over the left but not the right temporal lobes and the predominant involvement of the left but not the right temporal lobe in the awareness and memory of experiences.

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